I. C. 7461 APRIL 1948

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CONTROL OF ROOF AND PREVENTION OF ACCIDENTS FROM FALLS OF ROCK AND COAL

BY

J. J. FORBES AND H. J. SLOMAN

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CONTROL OF ROOF AND PREVENTION OF ACCIDENTS FROM FALLS OF ROCK AND COAL[1]

By J. J. Forbes[2] and H. J. Sloman[3]

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INTRODUCTION

This is the first of a series of information circulars dealing with the control of roof and the prevention of accidents from falls of rock and coal. These circulars are being published to focus attention of the coal-mining industry on this most prevalent source of fatalities and injuries and to present factual information that should be helpful in reducing loss from these causes.

Records of fatal accidents in the coal mines of the United States, from all causes, have been kept since 1906; during this period approximately 30,000 men have been killed by falls of rock and coal in the bituminous-coal mines, and more than 7,000 men have lost their lives in the Pennsylvania anthracite mines from the same causes. From 1906 to 1930, about 900 men were killed annually by falls of rock and coal in bituminous-coal mines, and about 200 men were killed annually in anthracite mines during the same 25-year period. From 1931 to the present time, the number killed annually from falls of rock and coal has averaged more than 500 men in bituminous-coal mines and about 125 men in Pennsylvania anthracite mines.

Numerically the record of accidents from falls of rock and coal shows improvement, but on a percentage basis and on a million-man-hours-of-exposure basis little, if any, improvement has been made during the past 40 years. The cold fact is that, year after year, about 50 percent of all those killed in coal mines in the United States lose their lives from falls of rock and coal.

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7461."

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The general public has a serious misconception as to the outstanding hazard in mining coal. Newspapers play up the infrequent occurrence of mine explosions because such disasters are sensational and spectacular. Nevertheless, about five times as many men are killed by falls of rock and coal as by explosions. In some years the ratio is 10 : 1 or even more but fatal accidents from falls are usually unspectacular. A fall-of-rock accident **rarely** kills more than one, two, or three men, and if mentioned at all, it wins only a few lines in the local press. Nevertheless, the annual toll of such accidents represents the most serious drain on the manpower of the coal-mining industry, because not only are approximately half the total fatalities but about one-fourth of the nonfatal accidents are due to **falls** of rock and coal. The latter figure represents 10,000 to 15,000 accidents annually, many of which are serious cases.

A question arises - is the coal-mining industry "licked" by this most serious hazard; has the industry reached the irreducible minimum so far as accidents from falls of rock and coal are concerned? It is believed that most of the leaders of the industry would be unwilling to admit that this hazard is insurmountable and that nothing more can be done other than what has already been done. It would be folly to assert that all such accidents can be avoided. Theoretically this may be true; actually it is a "target to shoot at," but, while a "bull's-eye" may never be scored, it is certain that the number of accidents from falls of rock and coal could be cut in half whenever the industry becomes really determined to do it.

THE PROBLEM

The control of mine roof and the prevention of accidents from unexpected falls thereof present no mystery. No reasonable person would say that such accidents are in the "Act of God" category. In a few outstanding exceptions, mine roof has collapsed unexpectedly, even when it was apparently supported adequately by coal pillars and timber. In the vast majority of cases where roof has collapsed with injury to one or more persons, it was because the pillars were unduly weakened or artificial support was inadequate in amount or too much time had elapsed before timbering was done or timbers had been removed without adequate replacements.

Before a building is erected, its dead weight and the loads it must carry can be calculated with reasonable accuracy. The roof of the building usually consists of several trusses, the design of which depends upon known loads, such as that due to dead weight, wind, snow, etc. The roof and floors of the building are supported on columns or walls the size of which can be made to carry the required loads without failure. If the roof of the building is primarily of structural steel, each roof-truss member can be designed accurately, and the proper steel section can be selected so that it will carry its load. The steel from which the various shapes (sections) are rolled is closely controlled during the steps in its manufacture; many tests are made, and its safe limits of tension or compression are accurately known. The supporting columns for the roof, if made of reinforced concrete, can be designed with a high degree of accuracy so that they will be strong enough to sustain their loads.

In contrast with the roof of a building, consider the roof of a coal mine. Roof in the average coal mine usually consists of coal, draw slate, shale, bony material, sandstone, limestone, clay, or mixtures of two or more of them. The material comprising the roof of a coal mine usually is stratified or laminated and is of variable texture. Mine roof is a "natural" product; its strength cannot be determined accurately like that of such material as structural steel. Moreover, flaws in steel can be detected by various tests, whereas mine roof may have joints, crevices, planes of weakness, and other irregularities, not visible or readily detectable, that may impair its strength. Extensive core drilling of a coal-mining property before actual mining is begun will not always disclose imperfections in mine roof; even when information is obtained it applies only to a limited extent and is applicable only to the specific place. Such coring may not disclose underground water courses, occluded gas, clay veins, horsebacks, or other unconformities that usually weaken mine roof. Mine roof is often referred to as good, average, or bad; but these are general terms, not separated by sharp lines of demarcation. To some compensation-insurance carriers the term "good roof" involves a hypothetical roof. For example, the Pennsylvania Bituminous-Coal Mine Compensation Rating Schedule contains the following definition:

> Good roof shall be hard slate, rock or coal roof, free from the following sources of danger: Slips, rolls, pots, cutters, clay veins, horsebacks, draw slate, alternating slate and rock, water crevices and crop roof. No roof which shows any defects shall be considered good.

According to this definition, it would be difficult, if not impossible, to have a coal mine whose roof was so devoid of defects throughout the workings that it could meet this specification for "good roof." From the safety standpoint, no roof should be considered "good" but should always be treated as hazardous.

It is safe to say that no coal-mine roof is so good it does not need support other than the pillars resulting from excavation. A structure like a steel-frame building is designed for a "state of rest or equilibrium." For example, if one of the principal supports of the roof of a building, such as a reinforced-concrete column, is removed, the stresses in the individual members of the roof truss differ from those for which they were originally designed. Thus the "state of rest or equilibrium" will be disturbed; and other stresses will be developed in the structural members, which, if not relieved by additional support or transference elsewhere to reestablish the equilibrium, will cause the roof to collapse. An analogy is drawn between the roof of a structure and the roof of a mine. Consider a block of coal that has never been mined; the coal and the overlying strata are in a "state of rest or equilibrium." After excavations due to mining have been made in the coal, the state of rest or equilibrium will be disturbed and must be reestablished. The equilibrium can be reestablished either by shifting all roof support to the pillars, as is sometimes done in driving narrow entries, or by furnishing additional artificial support, such as props, cross bars, walls of brick or concrete, and cribbing. If the state of rest or equilibrium is not thus reestablished, the only way the unbalanced stresses in the roof can be relieved is by caving the roof. Fall of roof is the major problem confronting the coal-mining industry because it kills and injures more workmen than any other single cause.

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The reestablishment of equilibrium of mine roof after mining is not necessarily an instantaneous operation. Some roofs will stand a considerable time without artificial support, but an outstanding reason why so many are killed by falls of roof is "wrong guessing" as to how long the roof will stand unsupported. Some roofs bend perceptibly before breaking, others break and fall without visual or audible preliminary warning, and still others give certain preliminary warnings. Because mine roof is a natural substance and not a manufactured product like steel, whose properties are known within close limits and whose composition can be closely controlled, the properties of mine roof can be determined only approximately. To prevent accidents from falls of roof, one cannot gamble safely with the time element of how long it will stand without artificial support like timbering, because ordinarily one does not have a second guess with a fall-of-roof accident. Some types of draw slate are so treacherous that they are not safe even when timbered; therefore, to avoid injury to workers, such draw slate must be taken down as soon as possible after having been exposed. Other types of roof are self-supporting until the mine atmosphere "weathers" it and disintegration begins; such roof usually "draws away" from the overlying strata before it collapses. Such roof must be timbered promptly before the weathering action can progress; after the roof has begun to weather it is usually too late for timber support and the bad roof must be taken down for safety. To paraphrase a well-known saying during World War II, the cause of many accidents from falls of roof is simply "too little or too late" with regard to adequate support.

WHAT HAS BEEN DONE TO SOLVE THE PROBLEM

A normal human being is endowed with five basic senses - sight, hearing, taste, smell, and feel - which serve as sentinels between him and danger. The senses of taste and smell are of no value in giving warnings with respect to the danger from falls of roof, but sight, hearing, and feel are of utmost importance.

The sense of sight permits a miner to observe the condition of his surroundings, note defects in the roof, and determine the adequacy of the timbering. When mine roof is so defective as to be obvious at a glance, a mine workman rarely will be so foolhardy as to walk or work under it.

A common method of testing mine roof is to use one's sense of hearing to "sound" the roof by striking it with a steel or wooden bar, a metal-tipped wooden rod, or a miner's pick. If a hollow or "drummy" sound is heard when the roof is struck, it is quite probable that the roof is dangerous and should be taken down or supported with timbers immediately. A dangerous piece of roof rock may be quite thick, so that it may not give off a hollow or drummy sound when struck with a bar or pick; in such instances, the quality of the sound alone may give a false sense of security with regard to the safety of the roof.

A more reliable method of testing roof is the sound-vibration method, in which the senses of hearing and feeling are utilized. This method consists of placing the tips of the fingers of one hand lightly against the roof and the free hand striking the roof sharply with a suitable testing bar. The vibration of the roof against the finger tips, coupled with the quality of the sound, will indicate the condition of the immediate roof better than sound alone. Obviously if the roof is too high above the mine floor to permit touching the roof with one hand, sounding alone must usually suffice. If the roof contains unexposed irregularities, such as slip planes or cracks, rolls or "horsebacks," "kettle bottoms," clay veins, gas feeders or blowers, or stump fossils, it may not be possible to determine the quality of the roof by either method of testing as outlined in the foregoing.

Mine workers have used both the sound and the sound-vibration methods of testing roof for many years, and some mining men think that these methods are too crude or primitive for ascertaining the true character of the roof. It has been thought that all workmen do not interpret the quality of the "sound" or "feel" of the roof, when struck, the same, so that where one workman may suspect danger another will not find cause for alarm. Such a conclusion has led to the search for better roof-testing devices. Some work has been done on developing an electronic roof-testing device of high sensitivity, so that sound and vibration beyond normal human detection through the senses of hearing and feeling are increased in amplitude and made readily discernible. It is hoped that this or some other device that is practicable and scientific will be developed for testing mine roof; such a device should be simple and rugged enough for use in coal mines.

Mine roof should be tested thoroughly and frequently throughout the work shift, but to know that danger is present and not take corrective action is one of the outstanding causes of accidents from falls of roof. The medical profession reveals that more people die from diseases of the heart than from any other so-called natural (nonaccidental) cause of death, yet is is safe to say that comparatively few people die from the first heart attack. In most cases the victim has had a previous attack or warning, failed to heed the warning or ignored, forgot, or neglected to observe the necessary precautions. Discovery of danger when a mine roof is tested is similar to a first heart attack; it is a warning that must be heeded by corrective action, or accidents from falls of roof will occur. Victims of roof-fall accidents, who survived their injuries, have been questioned as to whether they knew the roof was dangerous before it fell. Many of them have admitted that they knew the roof was bad but thought it would remain in place until they completed some particular task. For instance, a mining-machine man might have wanted to finish a "cut" of coal or a loading-machine operator completed a car of coal, or a miner loaded a car or laid a rail. Some victims of roof-fall accidents had not tested the roof to determine its soundness, but most victims knew of the danger through their own tests or those of officials but ignored the warning. Admittedly the sound and sound-vibration methods of testing are primitive; nevertheless, in many instances they are effective, and even if a satisfactory, more scientific device or method is developed it would at best only give a warning. A warning device would not set safety posts, erect cross bars, or take down bad roof. Although roof weakness may be amplified, the warning would be useless if ignored.

At mines where systematic methods of minimum timbering have been adopted and the supervisory staffs insist upon compliance by the mine workmen, notable reduction in accidents from falls of roof has been achieved; this fact makes it difficult to understand why systematic timbering has not been universally adopted.

Timbering machines have been developed to reduce the manual labor of setting cross bars; some have well-protected circular saws to cut timber to desired lengths. Aluminum-alloy beams have been developed for use as cross bars in coal mines; such beams have only a fraction of the weight of steel or wooden beams of comparable strength. Steel screw jacks have been developed to serve as safety posts or other temporary support; these can be erected quickly and securely. Effective means of erecting cross bars without legs have been developed for entry work; here the bars are supported on pins or short bars set in holes drilled into the rib or have the cross bars supported by elongated expansion bolts in holes drilled 6 to 8 feet into the roof. With all the improvements and labor-saving devices, the workers must still take the initiative for timbering where and when it is needed.

WHAT CAN BE DONE TO SOLVE THE PROBLEM

Fundamentally, the reduction of accidents from falls of rock and coal involves education of workers and supervisors, plus adequate supervision. A system of minimum timbering is a prime necessity; this establishes the number of rows of props, the distance apart in each row, and, if cross bars are needed, their dimensions and spacing. Minimum timbering may include cribs of certain size and their spacing, as used in some pillar-robbing operations; the system should include provisions for safety posts or other temporary timbers that should be set before permanent timbers can be erected. Prints of the minimum timbering requirements should be posted at conspicuous places in a mine; but, as some persons cannot understand a drawing or will not consult one, it is the duty of the supervisors to explain the timbering system in detail to the mine workmen and insist upon compliance.

One of the main reasons why adequate supervision is necessary in coal mines is not only to insist upon meeting minimum timbering requirements but to decide when the minimum must be exceeded. Minimum timbering requirements are determined by the study of and experience with mine roof. Studies involving the control of mine roof, convergence characteristics, weathering and caving characteristics, surface subsidence, etc., are valuable in determining minimum requirements for roof support. Such studies will supplement experience, but it should be reemphasized that mine roof is not a uniform product whose strength and characteristics can be calculated accurately by a mathematical formula.

A study of a large number of roof-fall accidents disclosed that about 85 percent of accidents from this cause occur within 50 feet of advancing working faces or pillars being extracted, as the case may be. Supervisors and workmen should understand that roof control involves both immediate and main roof. Immediate or secondary roof is the roof that causes most of the accidents from falls; immediate roof is that which is supported by ordinary timbers, such as props, cross bars, and safety posts. It lies directly above the coal being mined and may be a single layer or several layers of coal, rock, or rock mixed with coal ranging from a few inches to 6 or 8 feet in thickness. The nature and the thickness of the immediate roof usually determine whether it should be taken down or how it should be supported by timbering.

Main or primary roof lies above the immediate roof and ranges from a few feet to a thousand or more feet in thickness. It may be massive and unlikely to fall, except in parts of the mine where the coal has been removed over a large area such as in pillar workings or in longwall mining. Ordinary timbers used for supporting the immediate roof are usually inadequate for supporting the main roof. Timbers placed in the form of batteries, cogs, or cribs will help to control the main roof or may cause it to break along a predetermined line by forming an artificial shear zone. Some loss of life has occurred owing to unexpected collapse of main roof, such as in "bumps or bounces" in certain coal fields under extremely heavy cover or in caving operations coincident with pillar robbing. However, the majority of accidents from falls of roof occur from the collapse of immediate or secondary roof and not from the collapse of primary roof. Caving operations involving the removal of timbers and the breaking of primary roof are dangerous tasks; only the most experienced, competent men should do such work, and surprisingly few are injured because they recognize the hazards and know that relaxed vigilance may have fatal results. Therefore, it is not difficult to develop safety consciousness for such work.

Research to determine the characteristics of mine roof and to develop methods of mining that will result in the best possible methods of roof control is, moreover, highly desirable. The development of better roof-testing devices and timbering machines should be undertaken. As stated above, however, it must be remembered that neither research nor better labor-saving devices will set props or cross bars when and where they are needed. Human initiative is required and must be developed through proper instruction and direction and a willingness of those concerned to take prompt action.

Safety education is the keynote for eliminating accidents from falls of roof; it is necessary for both officials and workmen. Officials should be instructed in accident-prevention methods, not only to find what causes accidents and how they can be prevented but also to develop the methods by which the safety training can be effectively imparted to the workmen. Instruction of the workmen in safety is necessary to emphasize the first law of nature - self-preservation. Safety education should be as repetitive a process as eating but should not be made monotonous. If a person is given the same diet day after day, he would be likely to lose interest in eating; similarly if he has to hear a monotonous harangue on safety day after day he will lose interest in that also. Safety instruction can be made interesting, explanatory, and above all personalized for the individual without deviating from the basic concept - the avoidance of accidents, notably those from falls of rock and coal.

In some metal mines where compressed-air lines have been installed, it is an established practice to introduce a chemical - ethyl mercaptan - into the air lines to warn workmen to vacate the mine in an emergency, such as fire or flood. Ethyl mercaptan is a vile-smelling but harmless chemical that is added to the mine atmosphere, usually through the exhaust of pneumatic machines. Its presence indicates danger to all with a normal sense of smell and can never be doubted. It would be wonderful if some effective warning stench could be emitted when the roof becomes dangerous or a prop is needed in a working place. Close supervision and the development of safety-consciousness in the workmen are the most effective alternatives.

Instructing the workman to test the roof every time an official or any other person enters his working place is a good practice to encourage; but even if no one visits his place at hourly intervals, the roof should be tested that often, or more frequently if the roof is suspected of becoming dangerous. The workmen should be instructed that testing the roof is of value as a warning only if corrective action, such as timbering or removal of bad roof, is taken immediately.

Many mining-machine and loading-machine operators have been killed or injured by falls of rock or coal in places where too much unsupported space has been left between the face and the timbering. Props at or near the working face do interfere to some extent with the operation of a cutting or loading machine, but adequate timbering cannot arbitrarily be omitted solely because it might interfere with cutting or loading. A common cause of roof-fall accidents to machine operators is removal of props to permit their machines to be maneuvered, without setting temporary props to replace those removed. To avoid the inconvenience of props, temporary cross bars should be erected to support the roof above the working area of a machine. If a supervisor insists on proper timbering in face areas in which machines are operated, it is seldom difficult to gain compliance. Safety should not be neglected, and production will not suffer if timbering activities are coordinated properly in the cycle of operations at the working faces.

CONCLUSION

Accidents from falls of rock and coal can be prevented primarily by enforcing a minimum standard of timbering suitable for the mining conditions and by removing loose roof. Success of such a plan depends upon "teaching the teacher" - the supervisor. The supervisor must understand the characteristics of the roof and how to test it, and also the timbering requirements in situations necessitating more than the minimum support, so that he can properly instruct the workmen under his direction how to care for the roof and how to avoid accidents from unexpected falls of rock and coal. The workman, too, needs to be taught to protect himself by taking prompt action to pull down loose roof or to place or help to place suitable roof supports as soon as he realizes the presence of a hazardous roof condition. Production must not be maintained at the expense of safety. Good timbering and roof control are insurance against loss of production as well as loss of life or limb.

In conclusion, the coal-mining industry certainly has not reached its limit of the irreducible minimum of accidents from falls of rock and coal. Effective education and maintenance of timbering requirements could reduce accidents 50 or more percent below their present level if the workers and supervisors were sincerely determined to do their part to achieve this goal.